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Received & Inspected

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FCC Mail Room

18 July 2016

Office of the Secretary
Federal Communications Commission
445 12th St., SW, Room TW-A325
Washington D.C. 20554

Dear Sir,

Enclosed you will find a submission to the Federal Communications Commission's ET Docket No. 16-191 released on June 15, 2016. While this submission is from an individual, it summarizes about three decades of field work on radio and electrical-noise problems by the undersigned and many associates and coworkers. The effort has been supported by both government and commercial sponsors as well as unsupported work by the submitter.

The submission and the supporting documents clearly show that a serious noise-pollution problem exists, and that policies, administrative actions, new noise limits and new test techniques need to be established for all electrical and electronic devices sold within the United States. Noise pollution is a major problem affecting the performance of many electrical, electronic and radio systems operated by the U.S. government, commercial entities, educational organizations, and individuals as demonstrated by the documents provided with the submission. Many additional documents, too numerous to provide with the submission, are available to support this conclusion.

This is an early submission because of time limits imposed by prior travel commitments. If required, considerable additional information and documents can be provided should additional support be desired or needed.

Sincerely,

DOCKET FILE COPY ORIGINAL

Wilbur R. Vincent

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INTRODUCTION

This submission responds to Federal Communications Commission Public Notice DA 16-676 released on June 15, 2016 and titled **OFFICE OF ENGINEERING AND TECHNOLOGY ANNOUNCES TECHNOLOGICAL ADVISORY COUNCIL (TAC) NOISE FLOOR TECHNICAL INQUIRIY** as **ET Docket No. 16-191**.

The response consists of (1) an introduction providing general comments about the increase in the noise floor of the radio spectrum from VLF through the UHF bands, (2) a brief personal history of the submitter, (3) an appendix identifying documents supporting the submission, and (4) two hard copies of each document listed in Item 3.

The documents listed and separately provided are a very small sample of the total library of radio-noise and electrical-noise related documents accumulated over more than 50 years of the field experience of the submitter. All documents submitted are available for public release although most have had limited public distribution.

Early experience with radio-noise issues started during World War II when I was a maintenance man and Morse-Code operator at radio-intercept sites in the Pacific. Radio noise was not an issue to the military at that time in history because all nearby devices were designed to suppress all sources of radio noise. All vehicles, electric-power generators, lighting, electrical and electronic equipment were specifically designed to be radio-noise quiet. Radio interference was simply never encountered. My issued Hammarlund Super Pro receiver always operated with a natural atmospheric noise floor, and it was able to receive ionospherically-propagated signals originating from distant ultra-low-power sources. No case of man-made radio interference was encountered.

In this submission, and in the submitted reference documents, the term radio noise and radio interference is used. The terms noise, radio-noise, electrical-noise and radio-interference are generally interchangeable from the standpoint of this submission.

Considerable experience with radio-noise issues was obtained as indicated in the list of documents, where the earliest listed document was produced in 1979. Many earlier documents are in file formats that can no longer be read although hard copies are available. Additional documents are being added to my library as they are completed.

As indicated in the title pages of the listed documents, assistance was provided by a large number of individuals. Many other unnamed individuals also contributed to the results described in the documents. I am especially grateful to the many sponsors of the work described in the documents with special thanks to the organizations that sponsored the extensive field work.

PERSONAL HISTORY

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I obtained an amateur radio license (W8VYI) and a commercial broadcast license while in high school. Later, I held the radio amateur call of W2ZJR and now hold the call W6PUX. Working part time as a broadcast engineer in Radio Station WKAR permitted me to attend Michigan State College (now Michigan State University) during the ending years of the great economic depression. My college education was interrupted at the end of the sophomore year by service in the U.S Army Signal Corps during World War II with duty in New Guinea, the Philippines, and Okinawa. I returned to Michigan State College at the end of World War II and received the BS and MS degrees in Electrical Engineering.

In WW II, I was a radio-maintenance man and Morse-Code operator at radio-intercept stations in the Pacific. During overseas service, I had full-time access to a Hammarlund Super Pro receiver for general signal-reception tasks and for general roaming of the LF, AM and HF bands. During these early years, radio and electrical noise was virtually unknown. In the WW II intercept sites, all potential sources of noise (mainly gasoline and diesel generators and vehicles) were severely suppressed with effective shielding. Radio-noise and radio-interference problems simply did not exist. My rural location in Michigan for early amateur radio also did not have detectable sources of radio noise.

From 1955 to 1970, I was employed by the Stanford research Institute and organized and managed their Communications Research Laboratory. During this time, I became aware of radio-noise issues and spent several years working on radio-noise and radio-interference problems associated with electric-power lines, including the investigation of radio interference on the 800-kV direct-current Pacific Intertie from their associated massive dc-to-ac and ac-to-dc converters. During this early period, I became aware that many radio-interference problems were intermittent, and that only crude instrumentation was available to define the intermittent aspects of radio interference. After 15 years, I left the Stanford Research Institute (now SRI International) for small business. Later, I returned to SRI International for five additional years as a Research Scientist in the Radio Physics Laboratory. Subsequently, I became an Adjunct Associate Professor of Electrical Engineering at the Naval Postgraduate School, Monterey, CA. I retired from the Naval Postgraduate School in September 2009 and became a consultant to clients' investigating radio-interference-mitigation tasks at radio-receiving and data-processing facilities.

While in small business, I participated in the design and development of the Develco 3-Axis display, an instrument that provides a real-time, time-history view, of continuous and intermittent signals, and continuous and erratic interference, in the VLF, LF, MF, HO, VHF, UHF and microwave bands. This instrument is still used to define the temporal and spectral properties of both intermittent and continuous cases of radio noise. Its operation is described in several of the references in the appendix.

At the Naval Postgraduate School, Professor Stephen Jauregui, Dr. Richard Adler, Mr. Andrew Parker, numerous naval and other service students, and I used the 3-axis display and many other instruments for extensive investigations of radio-noise and radio-interference problems at a large number of radio-receiving and data-processing sites within the United States and throughout the world. The primary effort was known as the *Signal-to-Noise Enhancement Program* (SNEP) of the U.S Navy and with support from the U.S. Army. More than 70 detailed technical reports concerning the mitigation of radio interference at radio-receiving facilities were prepared for government agencies under this program. Extensive radio-noise mitigation actions were undertaken including the mitigation of both on-site and off-site sources.

The long duration of the SNEP program (three decades) allowed its participants, and me, to obtain a comprehensive understanding of the impact of noise on radio-receiving and data-processing facilities within the United States and abroad. It also allowed us to obtain and test instrumentation under realistic field conditions, including the successful mitigation of a large variety of on-site and off-site sources of noise. The SNEP program provided the experience and a background in radio-noise issues that became highly useful in more recent radio-noise investigations.

HISTORICAL COMMENTS ABOUT RADIO-NOISE

The early documents submitted in the appendix deal primarily with radio noise from electric-power distribution lines since hardware on distribution lines was the primary source of radio interference. While a number of earlier documents were completed in yet earlier years, they used early word-processing programs that are now unreadable. Fortunately, hard copies of most such documents do exist for reference purposes.

Sources associated with hardware on electric-power distribution lines continue to exist to this day. Such sources received considerable attention during early work, resulting in the first edition of the handbook titled *The Mitigation of Radio Noise from External Sources,* released in 1997. Subsequent editions of this handbook were produced until the latest 6th edition was released in 2007. The series of editions of this handbook were extensively used as instruction material for coworkers and many other radio-noise investigators. Of interest is that only very rare instances of radio interference from high-voltage alternating-current (ac) transmission lines were encountered during my field work. While corona noise was radiated from many transmission lines, the extremely low power of corona-noise sources limited radiation of harmful levels of radio noise to only a few yards from the transmission lines.

Relatively few other sources of radio noise were encountered in the early years. Some cases of narrow-band radio-interference from out-of-band ISM devices (mostly plastic-molding devices) were noted and are still found at today's receiving sites. Of interest is that discussions with some operators of these devices indicate that they sometimes change frequency for maximum performance, thus ignoring the official band limits since chances of detection were nil. A few intermittent cases of radio noise from nearby radio-frequency welders and other similar sources were occasionaly found, but the dominant source world-wide was hardware on distribution power lines.

Gradually over time, new kinds of sources, such as discharge lighting and switching power-conversion and power-control devices, were introduced into common use. Today, such devices are the dominant source of noise at radio-receiving facilities, in residential areas and at many business facilities. About two or three decades ago, the dominant source at homes, apartment complexes, businesses and radio-receiving facilities also transitioned from distribution power lines to digital-switching devices. This process was gradual and largely ignored until recently. The sources include a massive variety of new devices such as variable-speed motor drives, uninterruptible power supplies (commonly called UPS), switching power supplies, small 'Wall Warts' (the switching type) provided with many consumer products, and now a vast host of digital power-control devices. These devices are appearing in commercial facilities, government facilities, shopping centers, apartment houses, homes and are even installed in radio-receiving sites.

To cope with the introduction of digital switching devices into radio-receiving sites, a second handbook entitled *The Mitigation of Radio Noise and Interference from On-Site Sources at Radio Receiving Sites* was released in 2009. The two handbooks provided the basis for the mitigation of radio noise at government radio-receiving facilities, amateur radio stations, and commercial facilities.

Of interest is that not all digital-switching devices are harmful sources of radio interference. Some are effectively noise suppressed, but many are not. Many unsuppressed devices inject harmful levels of high-frequency noise current into power conductors, ground conductors, and other metallic objects of a facility. These conductors then distribute noise throughout a facility, and the electrically-long conductors efficiently radiate noise throughout a facility and even into the surrounding community. In many cases, such sources inject high levels of high-frequency noise current onto overhead distribution power lines serving the facility. Radiation from all such electrically-long conductors can result in harmful levels of radio noise over very large areas and for many miles from a source facility.

During the early part of several decades of radio-noise investigations, instrumentation to define the impact or radio noise on radio receivers, computers, data-processing systems, and other victim devices, suitable instrumentation always limited progress. This limitation was greatly complicated by the eventual understanding that most cases of radio noise were transitory and intermittent, but sometimes accompanied by steady-state radio noise. Instrumentation to define the properties of the primary noise problem, intermittent and erratic noise, has been and remains, a primary challenge. This led to an understanding that the mitigation of present-day radio noise requires an understanding of the nonstationary statistical nature of noise observed under field conditions as contrasted with Gaussian noise measured under laboratory conditions. While conventional standard statistical measures of radio noise were, and still are, sufficient to cope with cases of time-stable radio noise, they simply do not describe or define the more frequent cases of erratic radio noise. This greatly complicates obtaining a complete understanding of today's noise problem, especially under practical field conditions. The measurement procedures and instrumentation developed for time-stable laboratory measurements of noise are grossly inadequate for measurements under field conditions as demonstrated by the hundreds of examples of erratic radio noise provided in the documents accompanying this submission.

Still another problem was encountered during field work. Most sources of man-made noise are impulsive. The amplitude of both Gaussian-noise and impulsive-noise is a function of measurement bandwidth (or receiver bandwidth). To cope with this, all measurements were made with spectrum analyzers, or other devices, with Gaussian-shaped bandwidths. While amplitude changes with bandwidth for Gaussian noise is well understood, this is not the case for impulsive noise. It was necessary to develop practical amplitude-vs.-bandwidth plots for cases of impulsive noise from field measurements. Typical examples of this plot are provided in the accompanying references.

Another key obstacle to obtaining an understanding of radio-noise conditions in the field is the difficulty of making high-frequency noise measurements in accordance with the procedures of the FCC and other government standards. The FCC Rules and Regulations specifies the measurement of noise voltage and provides voltage limits for Class A and Class B noise sources. This is possible under laboratory conditions and extensive procedures and techniques have been developed by industry and government entities to measure and determine if electrical and electronic devices meet stated noise-voltage limits. These present procedures and techniques have been highly successful, especially to determine if devices under test meet the FCC Class A and Class B noise-voltage limit. The author has often purchased equipment and devices with the familiar Class B label.

Unfortunately, the laboratory procedures for the measurement of high-frequency-noise were found to be generally unusable under field conditions. This is because high-frequency radio noise from active sources is injected onto all conductors of a field facility. Standing waves of voltage and current exist on all electrically-long conductors of a facility, including power conductors, ground conductors, cable shields, equipment cabinets, building structural material, etc. Thus, a zero-potential reference for a high-frequency voltage measurement cannot be found in a practical radio, data-processing, residential, or industrial site that contains one or more harmful sources of radio noise. This impasse was avoided by using a current clamp to measure high-frequency current flowing in a conductor. Alternatively, electrical-field sensors were sometimes used to measure the voltage on a conductor. Fortunately, sensitive and broad-band high-frequency current clamps and some electric-field sensors are commercially available. Because of the ease of using a current clamp, most of the referenced documents provide noise levels on conductors in amperes. A few examples provide noise voltage levels from an electric-field sensor in volts. For examples collected at the input terminals of a radio receiver, amplitude is expressed in dBm. Since all measurements at a radio receiver were made with a 50-Ohm termination impedance, the dBm values can be converted to voltage or current.

Radio noise from most present-day sources is now broadband rather than discrete in frequency. This requires that broadband measurement techniques be used to define the amplitude and other properties for most field cases. Closely-spaced spectral peaks and nulls in noise amplitude prevent sampling radio noise at intervals across wide frequency bands. Fortunately, the popular spectrum analyzer solves this problem. It nicely displays the complex spectral properties of cases of intermittent and time-stable radio noise, including cases with discrete-frequency spectral components. High-dynamic range preamplifiers were used in front of the spectrum analyzers to achieve signal-detection levels comparable to standard HF, VHL, UHF and microwave receivers. Unfortunately, a standard spectrum analyzer cannot fully define the common cases of erratic radio noise (statistically nonstationary noise). While some analyzers now provide a time-history display, amplitude is often compressed in this view, and this limits the usefulness of such a presentation.

To define the spectral and temporal properties of erratic and/or continuous radio noise, the author used both standard scanning and Fast-Fourier-Transform types of spectrum analyzers along with the Develco 3-Axis Display to portray a moving real-time, time-history, view of the spectral and temporal properties of thousands of cases of radio noise. While this rather special instrument is old and aging, it has proven highly useful to define the properties of, and understand the adverse impact of, many cases of erratic and harmful radio noise from 30 Hz up into the microwave bands. Numerous examples of cases of harmful radio noise in the 3-axis format are described in the documents provided in the appendix.

Early on, additional instrumentation and associated analysis techniques were developed, such as the need to define each case of noise sufficiently to establish its impact on a victim system, define the temporal and spectral properties of each case of noise sufficiently to identify the class of its source, and to locate each source. Once these objectives were achieved, precise and effective mitigation actions could be formulated and implemented.

Questions in the Public Notice DA 16-676

My answers to the questions on Pages 2 and 3 of the notice follow where comments are directly related to each stated question. The documents provided in the Appendix (and hundreds of additional documents in my files) support my comments.

1. **Is there a noise problem**?
   a. *If so, what are the expected major sources of noise that are of concern?*
   Yes! A major noise problem exists. First, harmful level of radio noise from distribution power lines still exists. In addition, in the early 1990s, noise from digital power-conversion and power-control devices started to appear and adversely impact the performance of many kinds of victim devices. Such sources spread rapidly until now they are the dominant source of electrical and radio noise at most locations and for most victim devices. The sources include a great variety of switching power-conversion and power-control devices from switching types of Wall Warts up to megawatt-level switching devices. For example, it is estimated that radio-noise emanating from the power-conversion devices associated with many tall wind turbines will affect signal reception to high-frequency radio receivers 10 miles, or more, from a single wind turbine.
   b. *What services are being most impacted by a rising spectrum noise floor?*
   The national defense services are being adversely affected by electrical and radio noise. Residences and apartment buildings are also primary victims in that AM broadcast-band signal reception is often obliterated by noise. Amateur radio and government radio-receiving and data-processing sites are seriously affected.
   c. *If incidental radiators are a common concern, what sorts of government, industry and civil society efforts might be appropriate to ameliorate the noise they produce?*
   The FCC's Class B noise limits need to be expanded to cover all commercial solid-state-switching devices sold in the United States. Consideration needs to be given to a new set of more strict limits for residential use and for radio-receiving sites.

2. **Where does the problem exist?**
   a. *Spectrally*
      i. *If so, what frequency bands are of most interest?*
      The VLF, LF, MF, HF, VHF and UHF bands are all adversely impacted by noise. Noise problems also exist at higher frequencies in the unregulated wireless bands where the public is not aware of hidden radio-noise issues.
   b. *Spatially?*
      i. *Indoors and outdoors?*
      Both: Solid-state switching devices are becoming common in homes, business buildings, and other facilities for a wide variety of power-conversion and power-control tasks. These devices inject noise current into all of the electrically-long conductors of such facilities, and these conductors radiate noise beyond the walls and areas of such facilities.

ii. *Cities vs, rural settings?*
Both: More sources of noise are present in cities than in rural areas simply because of the higher density of sources. Nevertheless, solid-state and other switching devices are rapidly spreading into rural areas as indicated by the many references in the appendix describing noise problems in rural areas.

iii. *How close in proximity to incidental radiators or other noise sources?*
This varies from a few 10s of feet out to many miles. For example, the Wall Wart associated with my pacemaker/defibrillator monitor affects AM signal reception out to about 30 feet while a nearby tall wind turbine adversely affects MF and HF signal reception out to at least ten miles.

iv. *How can natural propagation effects be accounted for in a noise study?*
Practical propagation models exist for only a few special cases. The great variety of conditions, such as the immense variety of spectral and temporal properties of sources, the various configuration of conducting materials that radiate noise, the variety of attenuations and reflections of noise from building walls, construction materials, and terrain; make it difficult to develop useful models.

3. **Is there quantitative evidence of the overall increase in the total integrated noise floor across various segments of the radio-frequency spectrum?**

   a. *At what levels does the noise floor cause harmful interference to particular radio services?*
   Any radio noise exceeding the noise floor of an AM, FM or other radio receiver in any band will degrade the ability of that receiver to detect low-level radio signals. Any noise in a data-processing center that exceeds a threshold level of a victim circuit or device is harmful. While the noise floor will change from one type of receiver (or victim) to another, the noise-floor levels adversely affecting each victim can be established. Likewise, the tolerable level of each analog or digital victim to electrical or radio noise can be established as long as the temporal and spectral properties of the radio noise are known.

   b. *What RF environmental data from the past 20 years is available, showing the contribution of the major sources of noise?*
   See the appendix for examples of documents that are available. Several hundred additional and similar supporting documents are available.

   c. *Please provide references to scholarly articles and other sources of spectrum noise measurements.*
   See the appendix for examples of many available documents.

4. **How should a noise study be performed?**
   a. *What should be the focus of the noise study?*
   Fundamental work on ways to define and analyze cases of nonlinear and nonstationary signals and noise needs to be funded. Early work is summarized in the book *Nonlinear and Nonstationary Signal Processing* by Fitzgerald, Smith, Walden and Young. Additional theoretical and practical field work, directed specifically toward electrical and radio noise and its impact on victim devices, is urgently needed. In addition, a detailed review and open publication of much existing work is needed.
   b. *How should it be funded?*
   Federal funding is the only practical method.
   c. *What methods should be used?*
   A coordinated combination of theoretical and field work is essential. Theoretical work should be directed toward the solution of field problems with emphasis on nonlinear and nonstationary noise issues. A large collection of contract documents exists from the SNEP program (and related programs) that have had very limited distribution. Such documents will contribute considerable information to the data base needed to understand past and today's electrical and radio noise state. This needs to be followed by additional field work to define the spectral and temporal properties of radio noise emanating from such sources as shopping centers, industrial complexes, residential areas, solar farms, wind farms, and other potential sources of electrical and radio noise. Little is known about how to assess the impact of today's noise on operational systems, especially when nonstationary noise conditions are present. While the SNEP program developed a method of determining the impact of Gaussian noise on signal reception with HF radio receivers (known as the "Performance Evaluation Technique" (PET2A), this was an initial and limited effort.
   d. *How should noise be measured?*
      i. *What is the optimal instrumentation that should be used?*
      Select and use instrumentation for field work that is capable of defining the spectral and temporal properties of both time-stable and time-varying noise. In addition the instrumentation must be able to provide the spectral and temporal properties of each case of noise in sufficient detail for source identification and source location.
      ii. *What measurement parameters should be used for that instrumentation?*
      The spectral details of noise need to be sufficient to define peaks and nulls in amplitude over a band of frequencies. In addition, the temporal properties of impulsive noise change with frequency, and it needs to be measured in sufficient detail to define noise across a band of frequencies. This suggests the need for instrumentation, such as spectrum analyzers (equipped with high-dynamic range preamplifiers to achieve low noise floors), and advanced processing and display techniques.

iii. *At what spatial and temporal scales should noise be measured?*
Most noise appearing at victim devices is wide in bandwidth and with significant peaks and nulls in amplitude across a portion of the spectrum. While an amplitude accuracy of a few dB is desired, the frequency accuracy of modern instruments is sufficient. Precise frequency information is rarely or never needed to define broadband noise. Time accuracy is vital to define the shapes of time-stable and time-unstable impulses, and the periods of repetitive impulses, as well as the ability to distinguish and define noise from multiple sources.

iv. *Should the monitoring instrumentation be capable of determining the directions of noise sources? If so, how would those data be used?*
It is very helpful to determine the direction to noise sources external to a victim facility, and directional information is often necessary to conduct effective source-location and source-mitigation actions. Knowledge of the spectral and temporal details of radio noise is very helpful in identifying types of sources. Directional and information about noise properties, followed by the use of source-location instrumentation is the most effective approach to noise mitigation. Sources within a facility require different location techniques.

v. *Is there an optimum height above ground for measurements?*
In many cases an antenna at optimum height is not required to define the primary properties of noise. This is especially the case for source-identification, source-location and source-mitigation tasks. For cases where defining a noise environment is important, the antenna used for noise measurements should be of a type and height that can be scaled to fit that used by a noise victim.

e. *What measurement accuracy is needed?*
Because most present-day noise is broad in bandwidth and changes over time, high accuracy is not required for its definition. Occasionally, a discrete-frequency or narrowband noise will be encountered. The accuracy of modern instruments and receivers is entirely sufficient to cope with this limited kind of source.

i. *What are the statistical requirements for sufficient data? Would these requirements vary based on spectral, spatial and temporal factors?*
Standard and common statistical measures of amplitude (rms, average, peak and amplitude probability distributions) are sufficient to define specific cases of time-stable Gaussian and near-Gaussian noise. Spectral peaks and nulls require that amplitude measurements be made at specific frequencies of special interest, or that broadband measurements be made, such as with a spectrum analyzer. Cases of time-changing noise require more complex instrumentation, and it can only be described today graphically in three dimensions of amplitude, frequency and time, where impulse-shape and impulse-period of erratic sources must also be defined.

ii. *Can measurements from uncalibrated, or minimally calibrated devices, be used?*

If source location and mitigation is the primary goal, instrumentation with minimal calibration accuracy can be used. For the definition of the statistical properties of noise for comparison from one location to another, calibrated instrumentation and standard antennas are required. However, the frequency, amplitude, and time calibration of most modern instruments is sufficient for all but the most unusual cases of noise.

iii. *Is it possible to "crowd source" a noise study?*

Not likely with today's lack of suitable instrumentation at reasonable cost. Cases of time-unstable noise would impose instrumentation limitations on most participants in a "crowd sourced" noise measurement effort.

f. *Would receiver noise commonly logged by certain users (e.g radio astronomers, cellular, and broadcast auxiliary licenses)be available and useful for noise floor studies?*

Such measurements would be very useful to establish the occurrence of harmful levels of noise at a facility. But, they would probably not be sufficient to ascertain the impact of noise on a device or system, nor would it be sufficient to locate and mitigate a source.

g. *How much data must be collected to reach a conclusion?*

Only enough to document the properties of the noise and to locate and mitigate each source. In cases of intermittent noise, the measurement period must be long enough to encounter and define the noise. For example, noise measurements of some types of nearby wind turbines during weekends, or a holiday, would indicate it is noise free. Noise during a week day would show that the wind turbine is a primary source of interference to the MF and HF bands out to 10 or more miles.

h. *How can noise be distinguished from signals?*

In most cases, the temporal and spectral properties of today's noise can be distinguished from the temporal and spectral properties of signals. This includes time-varying noise and time-varying signals. The SNEP teams have been highly successful at distinguishing signals from noise.

i. *Can noise be characterized and its source identified?*

The kind, or type, of source can, in most cases, be determined from an examination of the temporal and spectral properties of its noise. This requires the accumulation of some experience since a wide variety of temporal and spectral signatures are generated from a variety of sources, and some sources produce time-changing spectral and temporal noise. The SNEP teams have been very successful at this kind of task. The location of a source some distance from a victim device often requires additional information, such as direction.

ii. *Is there a threshold level, below which measurements should be ignored?*

Yes. The minimum detection level of a desired signal in the presence of time-stable Gaussian noise is an excellent indicator of tolerable noise levels. For example, the noise floor of a standard HF receiver is about -130 dBm for a 3-kHz Gaussian-shaped bandwidth. This is equivalent to a rms. noise current of about 0.02 μA at the input terminals of a standard receiver with a 50-Ohm input impedance. Any noise exceeding this limit is harmful.

Appendix

EXAMPLES OF DOCUMENTS DESCRIBING RADIO NOISE CONDITIONS FOR A VARIETY OF CASES

This appendix provides a partial list of documents in my files related to electrical and radio noise found flowing on conductors and radiated in the VLF and up into the UHF frequency bands. This partial list of available documents is submitted to support aspects of the "**Introduction**", "**Historical Comments about Radio-Noise**" and the "**Questions**" sections of this response. The documents listed are a sample of several hundred such documents in my files, and they illustrate the extent of the effort made to understand and describe noise and interference conditions encountered over many years. The list of references is incomplete, and the list does not include many additional documents not released for public use. Hard copies of many earlier documents are also available. Since they were produced by the elementary word processors of early days, copies cannot be conveniently provided to accompany this submission.

Two copies of each document listed in this section are provided with this submission. Each document provided is identified by its release date in the *yy mm* format followed by the title of the document. This method of listing provides a partial historical record of progress during hundreds of noise investigations over several decades of intensive field work on real noise problems.

1979-02 Loran-C RFI and Noise, Los Angles, California
This is a detailed technical report describing the temporal and spectral properties of noise affecting the reception of Loran-C signals in Los Angles, California.

1979-05 Impulsive noise in the 3 to 300 kHz Band on Electric Power Utility Distribution Lines from a 1.6 MW Experimental Converter Bridge
The temporal and spectral properties of radio noise from an experimental power-conversion device are described.

1979-06 Electrical Noise in the 3 to 300 kHz Band on Electric utility Distribution Lines from a Transit System Rectifier.
A detailed record of noise affecting the reception of Loran-C and other signals in the 3- to 300-kHz band is provided.

1997-06 Technical Report NW9705A, Signal-to-Noise Enhancement Program Survey, NSGA Northwest

This report is one of a series of documents describing radio-noise mitigation efforts at the former radio-receiving site at Northwest, Virginia. This site was located at a remote location in the middle of a large swampy area on the border of Virginia and North Carolina. Nevertheless, it encountered significant radio noise from sources on distribution power lines serving residential areas located well outside the site's boundaries. In addition, two examples of radio noise from early digital-switching devices are documented in the submission. Since this facility was closed several years ago, and the agency supporting the work no longer exists, the report is submitted as an example of work done, and documents completed, at many other similar facilities.

1980-04 Temporal and Spectral Properties of radio Noise on the HVDC Pacific Intertie

The technical memorandum provides preliminary information about the temporal and spectral properties of noise emanating from an 800-kV, dc power line. This was an exploratory effort to understand the potential impact of the power line at rural locations.

1980-10 Loran-C RFI Measured in Los Angeles, California

This document provides detailed spectral and temporal properties of radio noise at a number of locations in Los Angeles, California. It shows that ambient noise is a major factor limiting the implementation of vehicular Loran C.

1981-01 Electric and Magnetic Fields Emanating from a Utility Power Line

An example of numerous technical memoranda prepared to describe noise emanation from electric-power distribution lines.

1983-05 Distribution-Line Harmonics and Noise at Export, Pennsylvania

A Technical Memorandum describing radio-noise conditions at a site containing welding and other equipment generating noise.

1983-05 Residential Electrical Noise Measurements

The document is a progress report on the measurement of radio noise from household objects at a house.

1985-10 Harmonics and Electrical Noise in Distribution Systems, Volume 1: Measurements and Analyses

A detailed record of the amplitude of harmonics and high-frequency noise emanating from a specific electric-power distribution line is provided.

1996-08 EMI from a Desktop Computer
Radio Interference from an early model of desktop computer was examined. The report provided information about high-frequency noise-current impressed onto cables connected to the computer. This was an early attempt to establish acceptable limits of noise current from computers and other devices installed in radio sites.

1998-03 The EMI Aspects of Grounds at Receiving and Data-Processing Facilities
A technical memorandum shows high-frequency current flowing on grounds at a radio-receiving and data-processing facility. Standing waves along the ground conductors of a site are described as well as standing waves along the shield of a test cable.

2001-06 Conducted EMI from an Engineering Model of a DC-to-AC Converter
A technical report describing conducted noise on power cables connected to an experimental model of a dc-to-ac converter constructed to power instrumentation in a water tank.

2002-09 Multiple GPS RFI Sources in a Small California Harbor
This paper describes severe GPS radio interference for small and medium vessels in a harbor on the Pacific Ocean. It was presents at Proceedings of the 15th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GPS 2002) on September 24 - 27, 2002

2003-10 Radio Interference from a Residential Solar-System Inverter
The document summarizes the severe radio interference encountered by a radio amateur from the installation of an early solar-power system.

2005-01 An Examination of Man-Made Radio Noise at 37 HF Receiving Sites
This document summarizes radio-noise findings at 37 HF receiving sites and over multiple visits to the sites over many years. It compares observed noise conditions to older and conventional descriptors of noise.

2007-05 The Mitigation of Radio Noise from External Sources
This is the 6th and last edition of this handbook. The handbook was periodically updated as experience was gained in the location and mitigation of sources external to a site. This edition has been widely used by government, industry, and amateur-radio operators as a guide in the mitigation of sources of radio noise external to a radio or data-processing site.

2009-11 The Mitigation of Radio Noise and Interference from On-Site Sources

Because of the long-range duration of the US Navy's "Signal-to-Noise Mitigation Program" (SNEP), extensive field measurements of radio and electrical interference were made over more than 20 years. In the early days of the program, the primary sources of noise were from sources external to radio sites and primarily from sources on distribution power lines. As the program progressed through the years, noise from sources within a site and associated with solid-state switching devices became more prominent. This handbook was generated to aid in the mitigation of sources within a radio or data-processing site.

2016-07 Radio-Frequency Emissions from a Small Wind Farm

This is a copy of a very recent submission to the Institute of Electronic and Radio Engineers (IEEE) Electromagnetic Society's magazine. It describes initial findings of severe noise in the HF band emanating from two wind turbines. The source of the noise was identified as the dc-to-ac power-conversion device contained within each of the two wind turbines. The converters injected high levels of high-frequency current and voltage onto the 100-ft towers supporting the turbines, and temporal and spectral properties of radiation from the towers is described as well as the parasitic impact of the rotating blades on noise properties. Additional measurements at large wind farms have provided similar noise results, although with somewhat different and unique temporal properties.

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Report No. 6893/6894-0279 February 15, 1979

TASK I - PHASE II

LORAN-C RFI AND NOISE
LOS ANGELES, CALIFORNIA

Prepared for:

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PREFACE

A prior report entitled "Task I - Phase I, Loran-C RFI and Noise, Los Angeles, California," described the results of field measurements of noise and RFI at and near 100 kHz which were made during the period of December 18 through December 22, 1978. Additional field measurements were made in Los Angeles during the period January 22 through January 26, 1979. The results of these additional measurements are described in this report (Task I - Phase II). Data presented in the Phase I report are not repeated in this document. Thus, both reports are necessary to obtain a complete record of the Los Angeles measurements. Interested readers are urged to obtain both reports since some aspects of the instrumentation and measurement procedures were changed during the second measurement period, and additional sites and areas of Los Angeles were examined during the second measurement period.

Both documents are self-contained in that each contain a complete description of the measurements and results obtained from their respective field measurement periods.

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1. INTRODUCTION

Radio noise and RFI at and near frequencies employed by Loran-C radio navigation systems were investigated in portions of Los Angeles, California. Emphasis was placed on the definition of the detailed time and frequency domain structure of noise and RFI which might degrade the reception of Loran-C signals in urban, suburban, and industrial areas of Los Angeles. Furthermore, the measurements were directed toward obtaining an understanding of the noise and RFI environment which would be encountered by vehicularly-installed Loran-C navigation systems.

The measurements were made at and around the 100 kHz band of frequencies employed by Loran-C, and they were made from a mobile van. An attempt was made to duplicate the vehicular antenna installation employed by many Loran-C receiving systems and to achieve a signal detection sensitivity comparable to Loran-C receivers. The noise and RFI instrumentation was somewhat different than the instrumentation used for conventional measurements, and it is described in Section 2. While the instrumentation was capable of collecting data to provide comprehensive statistical descriptors of noise, this was not done. The measurements were primarily of a diagnostic nature where data were rapidly collected at a very large number of sites and during mobile operation. These data were employed to achieve an understanding of the detailed properties of noise and RFI at each site and while moving along streets and highways. The output format of the data, Polaroid photographs of calibrated 3-axis views of noise, RFI and Loran-C signals, was chosen to provide a simplified and rapid means of describing noise and RFI at each site and to permit the comparison of conditions from site to site. In addition, an attempt was made to gather data which would permit the comparison of actual noise and RFI conditions with the performance of Loran-C receivers installed in mobile vehicles.

The measurements described in this report were made during the period of January 22 through January 27, 1979.

2. INSTRUMENTATION

The instrumentation used to acquire data presented in this report is described in Figure 1. A standard 108" long whip antenna was employed to sense signals and noise. A low noise preamplifier was used to achieve a signal detection capability roughly equivalent to the RF sensitivity of a Loran-C receiver. An RF bandpass filter was available when needed to prevent intermodulation product generation in the low noise preamplifier and subsequent stages from nearby radio stations and nearby strong broadband noise sources. However, most of the data were taken without the RF filter. A Hewlett-Packard Series 140 Spectrum Analyzer was employed as a scanning receiver to drive an EMTEL Model 7200B 3-Axis Display. The 3-axis display provided a moving real-time visual representation of signals and noise received by the scanning receiver.

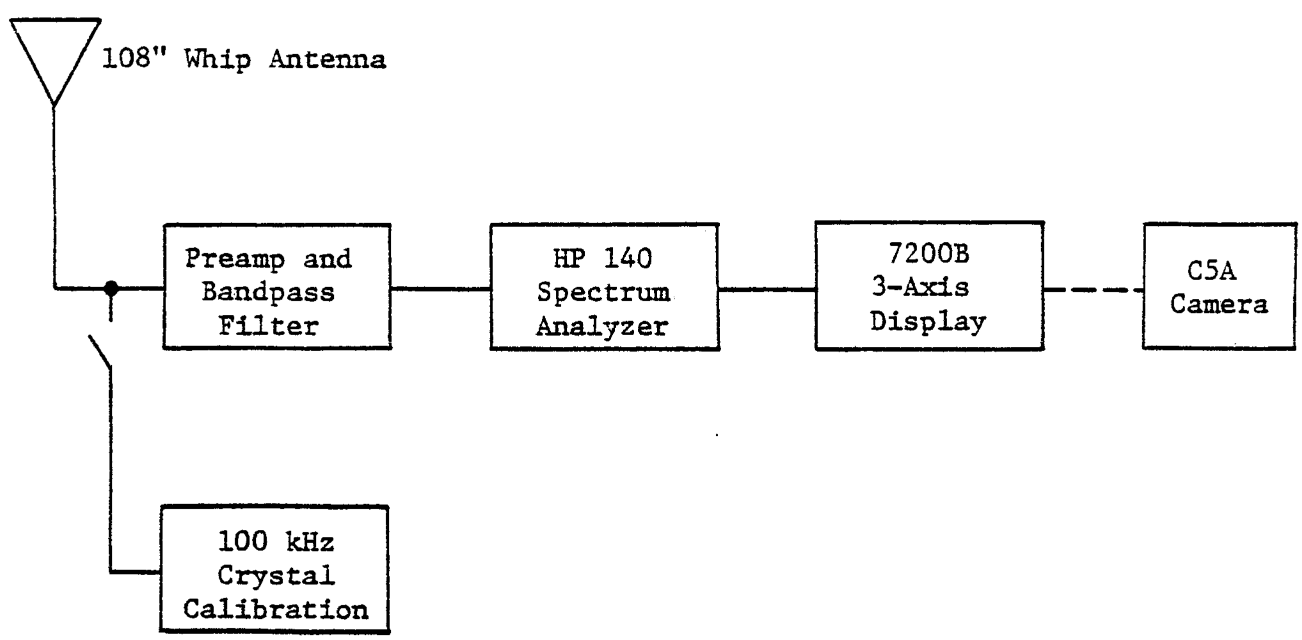


Figure 1 Block Diagram of Noise and RFI Measurement System

The instrumentation was installed in an Econoline van for mobility and convenience in noise and signal measurements. The van was driven to specific sites and street intersections selected by Gould Inc. for measurements and to a few other locations identified as potential problem areas. Both mobile and fixed location measurements were made as necessary to define a particular noise or signal situation.

To acquire data the spectrum analyzer was adjusted to scan across a block of frequencies centered at 100 kHz. As the spectrum analyzer scanned through a block of frequencies, its output was divided by the 3-axis display into 512 equally spaced data points. The received signal or noise amplitude at each data point was represented by an 8-bit digital word which provided an amplitude resolution of 256 levels for each data point. When a scan was completed, the 512 amplitude words were stored in memory and then presented as line 1 on the display CRT. When the second scan was completed, its data were stored in memory, line 1 on the CRT moved to line 2, and the new scan was shown on line 1. Subsequent scans moved the earlier data lines step by step along the time axis until the entire memory was filled and a total of 60 scan lines were presented in the 3-axis view. When the memory was full, each new scan caused the oldest scan to be discarded. The resulting animated moving view of signals and noise provided a unique and easy-to-interpret visual picture of noise and signals in the blocks of frequencies under observation.

The 3-axis display system has a number of controls to assist the operator in interpreting the signals. Among these controls are a stop-action control to freeze any desired view for detailed observation, geometry controls to vary the viewing aspect, display mode controls to select any segment of the total view for detailed examination, and a threshold control to vary the background noise level.

The 3-axis views presented in this report were obtained by photographing the display in its stop-action mode. In interpreting the data, consideration must be given to situations where repetitive impulsive signals are observed by the repetitive scanning process. The relative repetition rates of impulsive signals and the scan rate of the receiver produce distinctive bands that slant across the CRT.

System calibration factors necessary to accurately scale the 3-axis views are as follows:

Preamplifier Gain With Filter	18 dB
Preamplifier Gain Without Filter	15 dB
30 kHz IF Bandwidth Amplitude Calibration Factor	0 dB
10 kHz IF Bandwidth Amplitude Calibration Factor ...... (Apply to Loran-C and noise but not to CW signals)	8 dB
3 kHz IF Bandwidth Amplitude Calibration Factor .... (Apply to Loran-C and noise but not to CW signals)	12 dB
1 kHz IF Bandwidth Amplitude Calibration Factor .... (Apply to Loran-C and noise but not to CW signals)	20 dB

The RF bandwidth of the preamplifier filter is shown in Figure 2. Appropriate gain vs. frequency calibration factors for views which used the filter can be scaled from the filter bandwidth curve.

To accurately scale the absolute amplitude of Loran-C, noise, and CW signals at the antenna output (or preamplifier input), the system calibration factors must be applied to the amplitude scale on each set of 3-axis views in this report. These system calibration factors can be applied as described in the following steps.

1. An 18 or 15 dB factor has been applied to all 3-axis display amplitude scales to account for preamplifier gain.
2. Use the appropriate IF bandwidth factor:
   a. If the IF bandwidth is 10 kHz, add 8 dB to each Loran-C or noise amplitude measurement.

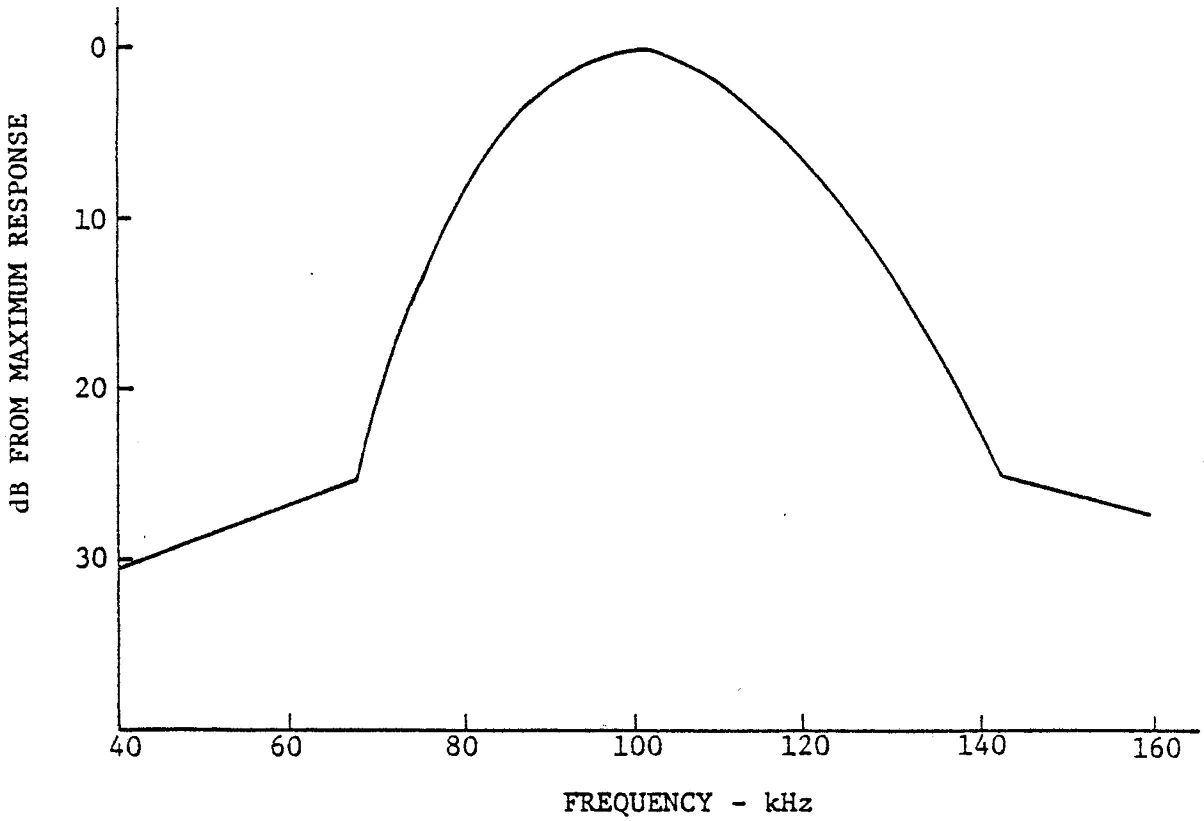


Figure 2 Preamplifier Bandpass Filter Response

b. If the IF bandwidth is 3 kHz, add 12 dB to each Loran-C or noise amplitude measurement.

c. If the IF bandwidth is 1 kHz, add 20 dB to each Loran-C or noise amplitude measurement.

3. If the preamplifier bandpass filter was used and if the measured noise, Loran-C, or CW signal amplitude is more than ± 10 kHz from 100 kHz, obtain an RF bandpass calibration factor from the filter characteristic curve and add this dB value to the measured amplitude.

The noise, Loran-C, or CW received signal levels obtained after taking the system calibration factors into account will describe the signal level available to a Loran-C receiver when connected to a mobile 108" whip antenna. These values can also be used to convert measured received power into field strength values by employing appropriate antenna conversion factors.

3. PRESENTATION OF SIGNIFICANT DATA

3.1 GENERAL APPROACH

The first phase of a field measurement effort to investigate and ascertain the performance of Loran-C receivers installed in land vehicles was conducted in late 1978 in the Los Angeles area by Gould Inc. These measurements identified certain streets, street intersections, and areas where unusual radio noise and RFI conditions existed. The noise and RFI at selected locations and along selected streets was examined in detail by Systems Control, Inc. (SCI) in December of 1978, and the noise and RFI conditions were described in the Task I - Phase I report [1].

The late 1978 measurements of Loran-C receiver performance in the Los Angeles area were continued into early 1979 at additional locations and areas not previously examined. During the week of January 22 through January 26, 1979, the SCI radio noise and RFI measurement van accompanied the Gould Inc. mobile Loran-C receiver measurement van to a number of sites selected by Gould Inc. personnel. The sites selected were typical of expected operational areas for municipal vehicles and other vehicles which might be equipped with Loran-C navigation systems at some future time. Loran-C receiver performance measurements were made by Gould Inc. at each selected site simultaneously with measurements of radio noise and RFI by SCI. The noise and RFI measurements are presented in this report.

In addition to measurements at predetermined sites, supplementary measurements of noise and RFI were made while traveling from site to site, at locations close to the fixed sites, and at additional locations of special interest. The results of these supplementary measurements are also presented in this report.

The noise and RFI measurements described in the Phase I report employed a bandpass filter in the matching network between the antenna and the preamplifier. The use of the filter required that a bandwidth calibration factor be applied to the amplitude of signals and noise below about 90 kHz and above about 110 kHz. The filter was used to ensure that strong CW signals and wideband noise would not saturate the preamplifier and cause unwanted intermodulation products to appear in the 3-axis views. The filter was successful in that intermodulation products were not encountered in the Phase I measurements. An alternate preamplifier with a wideband filter was constructed for the Phase II measurements. The preamplifier with the wideband filter was employed for most of the Phase II measurements, although some of the early measurements and some measurements in areas where high level, wideband power line noise was encountered were made with the Phase I narrowband unit. Data taken with the narrowband filter are clearly labeled.

Each 3-axis view is identified by a two-line code where the top line gives (1) the date of measurement, (2) the local time of day of the measurement, and (3) the site location or site identification number. The second line gives a number of system-oriented parameters, where the various parameters are (1) the model of scanning receiver (always an HP 140 Spectrum Analyzer for the Phase I and Phase II measurements), (2) the antenna (always a 108" whip), (3) the center frequency (F), (4) the frequency scan width (W), (5) the IF bandwidth, and (6) the scan time (ST). The last item consists of three numbers necessary to establish an amplitude calibration for each view where the first number gives the IF calibration factor for the HP 140, the second number gives the HP 140 RF attenuator setting, and the third number gives the RF preamplifier gain. When the letters NF follow the three amplitude calibration numbers, a broadband RF filter was employed and amplitude versus frequency calibration factors are not required. When the letters BPF appear, this indicates an RF bandpass filter was used and amplitude versus frequency calibration factors from Figure 2 must be applied to the 3-axis view.

3.2 FIXED SITE MEASUREMENTS

An extensive geographic survey of the greater Los Angeles area had been completed by Gould Inc. prior to the Phase II effort. From this survey a number of sites were selected for detailed measurements of Loran-C receiver performance and for radio noise and RFI measurements. Gould personnel had precisely located each measurement point, determined the best travel route from site to site, and categorized the general features of each site. The Gould Inc. site identification numbers and site categories have been used in this report to simplify the task of comparing the results of the two measurements.

A three-letter code was used to identify the particular municipal areas selected for joint measurements. This code was followed by three additional numbers which identified the sites selected for measurements. The municipal area codes are given in Table 1. Table 2 provides a convenient summary of the measurement locations, site identification numbers, the general activity in the vicinity of each site, the heading of the Gould Inc. measurement van along the street, and the presence or absence of nearby electric utility power lines.

Table 1 Identification Numbers for Municipal Areas

Municipal Area	Identification #
El Segundo	104
Torrance	106
Southgate	107
Compton	108
Carson	109
Lincoln/Boyle HTs	110

Table 2 Loran-C Site Survey Data

	SITE ID #	STREET INTERSECTION*	SITE CATEGORY**	MEAS. VAN HEADING	POWER LINES†
REGION 6 TORRANCE	106-001	Artesia/Van Ness	C	W	1
	106-002	178th/Falda	R	W	0
	106-003	182nd/Crenshaw	C	E	$\underline{1}$
	106-004	190th/Prairie	I	E	$\underline{2}$
	106-005	Fisk/Spreckels	R	S	0
	106-006	Redbeam/Towers	R	N	0
	106-007	Anza/Torrance	C	N	1
	106-008	Maricopa/Madrona	O	N	0
	106-009	Crenshaw/Dominguez	I	N	1
	106-010	Del Amo/Crenshaw	I	E	$\underline{2}$
REGION 9 CARSON	109-011	182nd/Wall	R	S	0
	109-012	192nd/1800' west of Avalon	O	E	0
	109-013	Dominguez/Avalon	C	E	0
	109-014	Carson/Orrick	C	W	1
	109-015	Avalon/223rd	C	S	$\underline{1}$
	109-016	Wilmington/Sepulveda	I	N	1
	109-017	Sepulveda/Alemeda	I	W	$\underline{2}$
	109-018	Watson Center/Wilmington	I	E	0
	109-019	Tillman/Denwall	R	N	0
	109-020	Brenner/Annalee	R	W	0

* Intersection shows location of van as first street listed (i.e., 3rd/Vine = van on 3rd).

** Site category: C - commercial, R - residential, I - industrial, O - open.

† Power lines show number of lines present (one side or both sides of street): 1 - one side, 2 - both sides, underline of number - van directly under lines.

Table 2 (Continued) Loran-C Site Survey Data

	SITE ID #	STREET INTERSECTION*	SITE CATEGORY**	MEAS. VAN HEADING	POWER LINES†
REGION 8 COMPTON	108-021	Wilmington/Walnut	I	N	$\underline{1}$
	108-022	Acacia/Carob	I	S	0
	108-023	Compton College Parking Lot (500' north of Artesia/west of Delta)	O	S	0
	108-024	Johnson/Alemeda	I	E	$\underline{1}$
	108-025	Tichenor/Oleander	R	W	1
	108-026	Mayo/Myrrh	R	N	0
	108-027	N. Sloan/E. Palmer	R	S	1
	108-028	Rosecrans/Santa Fe	C	E	0
	108-029	Rosecrans/Matthisen	C	W	$\underline{1}$
	108-030	Alondra/Wilmington	C	E	1
REGION 7 SOUTHGATE	107-031	Rayo/Firestone Pl.	I	S	1
	107-032	Firestone Blvd/Atlantic (on Dorothy 400' north)	C	W	1
	107-033	Dorothy/Firestone Blvd.	I	E	1
	107-034	Otis/Ardmore	I	N	$\underline{2}$
	107-035	State/Firestone Blvd.	C	S	0
	107-036	Tweedy/State	C	E	0
	107-037	Sequoia/Mariposa	R	E	0
	107-038	San Gabriel/Tenaya	R	S	0
	107-039	Kauffman/Duane	R	N	0
	107-040	Parking lot northeast of Hildreth/Duane	O	W	0

* Intersection shows location of van as first street listed (i.e., 3rd/Vine = van on 3rd).

** Site category: C - commercial, R - residential, I - industrial, O - open.

† Power lines show number of lines present (one side or both sides of street): 1 - one side, 2 - both sides, underline of number - van directly under lines.

Table 2 (Continued) Loran-C Site Survey Data

	SITE ID #	STREET INTERSECTION*	SITE CATEGORY**	MEAS. VAN HEADING	POWER LINES†
REGION 10 LINCOLN/BOYLE HEIGHTS	110-041	Terrace Heights/Penrith	R	W	0
	110-042	4th/Soto	C	E	$\underline{1}$
	110-043	Evergreen Cemetary at Evergreen/Michigan	O	N	0
	110-044	St. Louis/Michigan	R	S	1
	110-045	Murchison/Lancaster	C	N	1
	110-046	Soto/Multnomah	I	N	$\underline{1}$
	110-047	Mission/N. Broadway	C	S	$\underline{2}$
	110-048	Zonal/Griffin-Mission	I	W	1
	110-049	Gallardo/Mission (bottom of bridge)	I	S	0
	110-050	Kearney/Pennsylvania	R	E	1
REGION 4 EL SEGUNDO	104-051	Flournoy/36th	R	W	1
	104-052	Rosecrans/Highland	C	W	1
	104-053	Parking lot west of Grand/Vista Del Mar	O	E	0
	104-054	Mariposa/Loma Vista	R	E	1
	104-055	Whiting/Holly	R	N	0
	104-056	Eucalyptus/Grand	C	S	$\underline{1}$

* Intersection shows location of van as first street listed (i.e., 3rd/Vine = van on 3rd).

** Site category: C - commercial, R - residential, I - industrial, O - open.

† Power lines show number of lines present (one side or both sides of street): 1 - one side, 2 - both sides, underline of number - van directly under lines.

Three special sites were selected by Gould Inc. for daily measurements of Loran-C receiver performance. These sites were the Los Angeles Coliseum, Broadway and Pico, and the Los Angeles Municipal Transportation Authority Building at 425 Main Street. Figures 3 and 4 show typical conditions at the Los Angeles Coliseum. Very little radio noise was encountered, but three CW signals of modest strength and two weak CW signals are shown in the 3-axis views taken on 1/24/79 and 1/26/79. The relative amplitudes of each of the received signals at the Coliseum with all calibration factors applied are:

Frequency	Approximate Level
80 kHz CW	-86 dBm
90 kHz CW	-80 dBm
100 kHz CW	-86 dBm
108 kHz CW	-105 dBm
119 kHz CW	-80 dBm
Loran M	-78 dBm
Loran W	$<$ -93 dBm
Loran X	-73 dBm
Loran Y	-63 dBm

Figure 5 illustrates RFI conditions at Broadway and Pico. The 100 kHz CW signal increased in level substantially over that observed at the Coliseum site, while the 80 kHz and 90 kHz CW signals were much lower in level. Impulsive noise was not present. The relative amplitudes of each of the signals in the 3-axis view are:

Frequency	Approximate Level
80 kHz CW	-88 dBm
90 kHz CW	-90 dBm
100 kHz CW	-76 dBm
108 kHz CW	-92 dBm
119 kHz CW	-80 dBm
Loran M	$<$ -93 dBm
Loran W	$<$ -93 dBm
Loran X	-70 dBm
Loran Y	-63 dBm

1/24/79, 0730, Coliseum
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

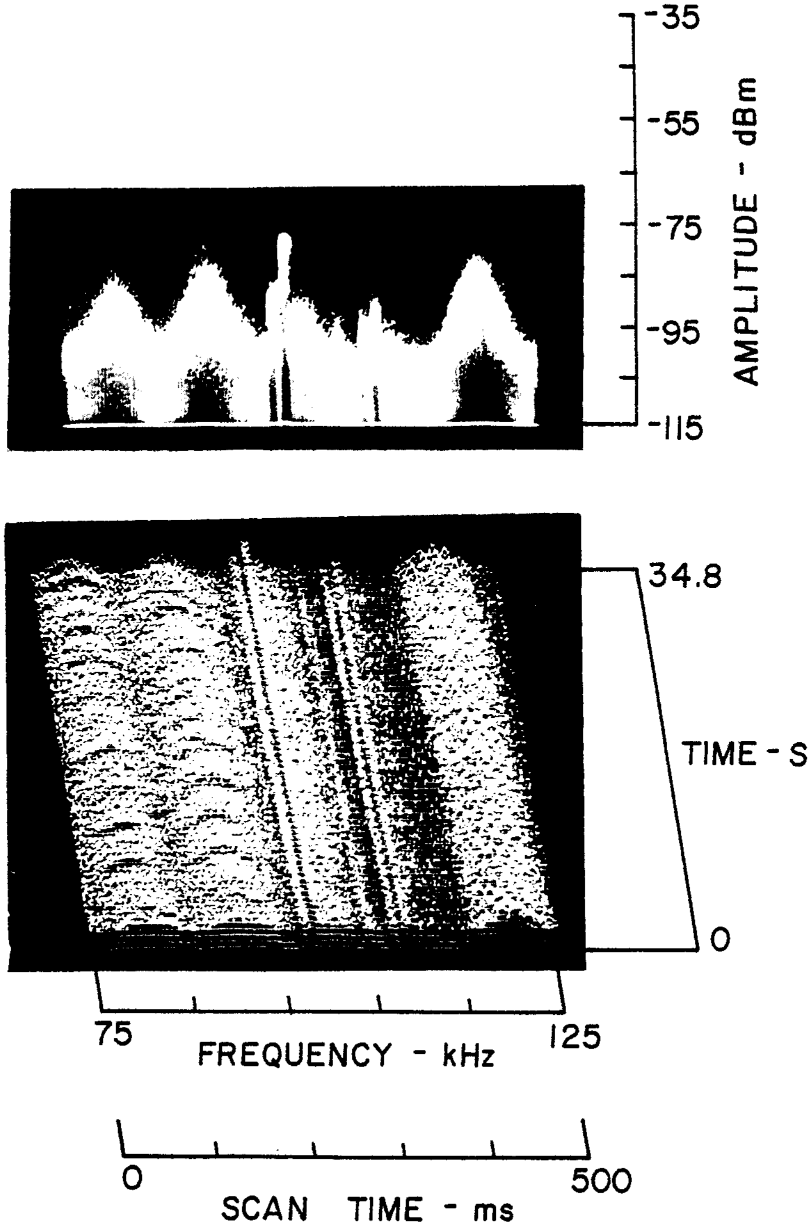


Figure 3 3-Axis View, 1/24/79, 0730, Coliseum

1/26/79, 0748, Coliseum
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

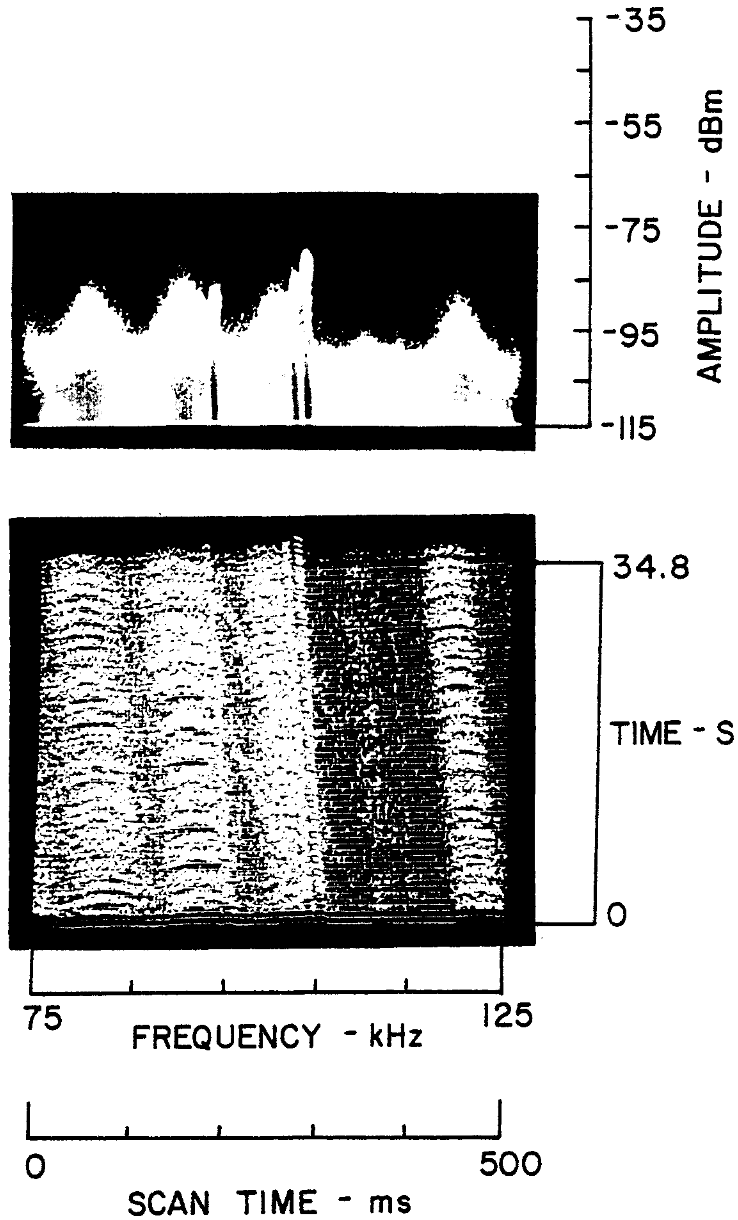


Figure 4 3-Axis View, 1/26/79, 0748, Coliseum

1/24/79, 0715, Broadway & Pico
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

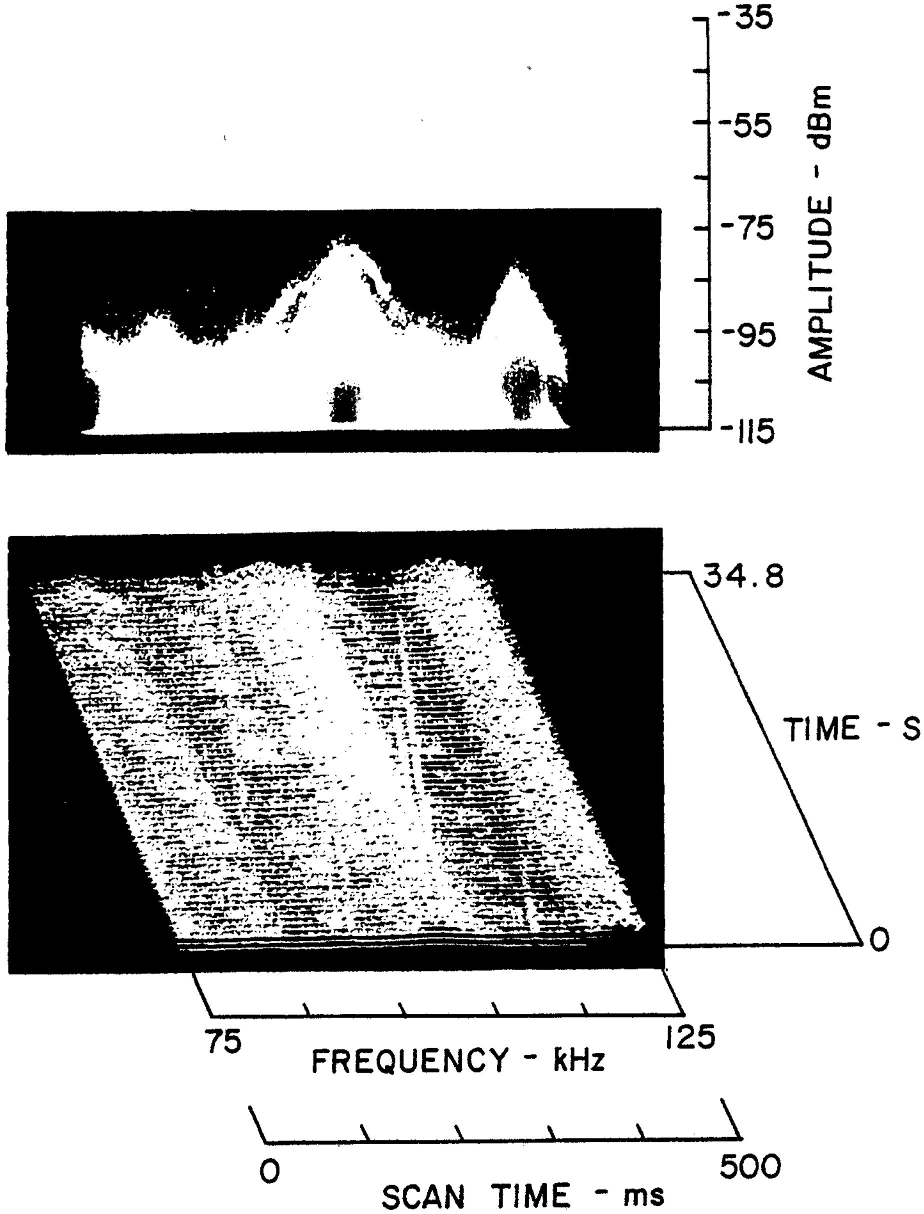


Figure 5 3-Axis View, 1/24/79, 0715, Broadway and Pico

Figure 6 illustrates signal reception at 425 Main Street, a site immediately adjacent to a large multiple story building. Neither CW nor Loran-C signals could be detected at the site, and noise levels were the lowest of all sites measured in the Los Angeles area. The nearby building obviously became part of a physical structural arrangement that severely attenuated all LF radio signals.

Loran-C, radio noise, and RFI at the various sites selected for detailed examination are shown in a sequence of fully calibrated 3-axis views in Appendix A. A pair of views were taken at each location with fixed scanning receiver adjustments of F = 100 kHz, W = 50 kHz, IF = 3 kHz, and ST = 500 ms. Where unusual conditions existed, additional views were taken using other receiver adjustments. These additional views follow the standard views, and they contain the same site identification code as the standard view. The time of day and some of the receiver adjustment parameters will be changed. These differences can be seen in the two-line set of parameters on each pair of views.

The reader can scan through the 3-axis views in Appendix A to observe the changes in noise, RFI, and Loran-C signal levels from site to site. The variety of noise and RFI from site to site is impressively diverse. This variety clearly warns against making simplistic conclusions concerning the noise and RFI. Furthermore, the wide variety of conditions suggests that average values of noise and average RFI states by themselves have little meaning.

1/24/79, 1353, 425 Main St.
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

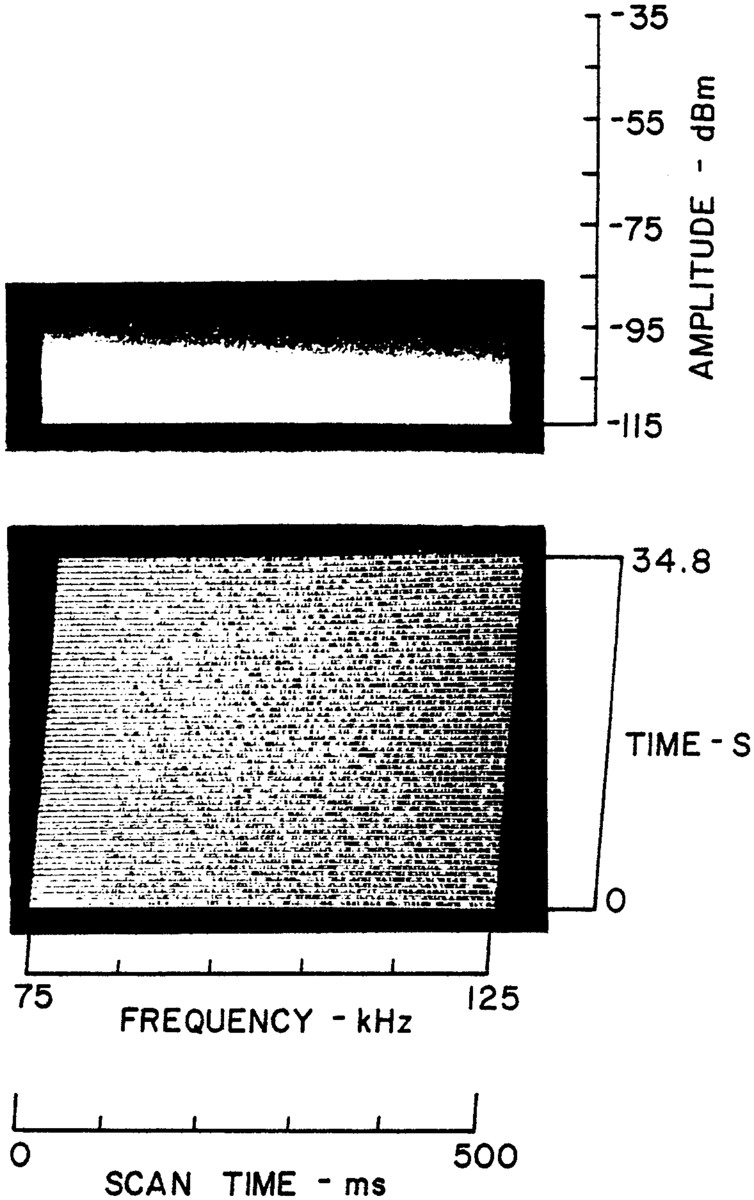


Figure 6 3-Axis View, 1/24/79, 1353, 425 Main Street

3.3 SUPPLEMENTARY MEASUREMENTS

3.3.1 General Description

The Phase I measurements showed that noise and RFI conditions frequently and usually changed over very short distances. Signal and noise levels were shown to vary in peak level by more than 40 dB over distances of less than 100'. Such variations would not be evident from the fixed location type of measurements described in Section 3.2 and Appendix A. Thus, as time permitted, additional measurements were made while approaching and leaving the fixed sites and at other sites of special interest. These measurements were made to provide a more complete understanding of the spatial characteristics of the noise and RFI.

3.3.2 Spatial Variations in CW Signal Levels

The 3-axis views in Figures 7 through 10 show typical variations in CW field strength as the measurement van moved along a street. Figure 7 shows four CW signals varying in amplitude as site 106-010 was approached. Amplitude variations of 10 to 30 dB can be seen in the view where the CW frequencies are about 80, 100, 108 and 119 kHz. This view can be compared with the 3-axis view of site 106-010 in Appendix A where the 100 kHz signal is very weak, and the 108 and 119 kHz signals are a few dB higher in strength.

Another example of large variations in CW signal strength is shown in Figure 8. The view was taken about 200' from site 109-014, and it shows a very sudden decrease in strength of a CW signal at about 88 kHz, while the signal at about 118 or 119 kHz remained constant in amplitude. The 88 kHz signal was not visible in the view for site 109-014 in Appendix A. The view in Appendix A also indicates mild impulsive noise across the entire 50 kHz block of frequencies shown.

Figure 9 shows an abrupt change in CW signal levels as the measurement van turned off Sepulveda onto Wilmington. Both 3-axis views shown in Figure 9 contain the same data at different viewing aspect angles. Weak CW signals at 80 and 90 kHz did not change in signal level, while the 100 kHz signal decreased in strength and the 119 kHz signal increased in strength. Merely turning around the corner resulted in substantial changes in the CW signal environment.

Figure 10 shows a change in CW signal and noise environment noted as the measurement van moved along Wilmington. The two portions of the view were taken at locations about 1/2 mile apart. The 80 and 90 kHz CW signals increased in amplitude by a small amount, and the 119 kHz signal decreased in level. A 100 kHz signal can be seen in the lower portion of the view but not in the upper portion. Impulsive noise was present at the second site, as shown in the lower portion of the view, but not at the first site, as shown in the upper portion.

1/22/79, 1220, approaching 106-010
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

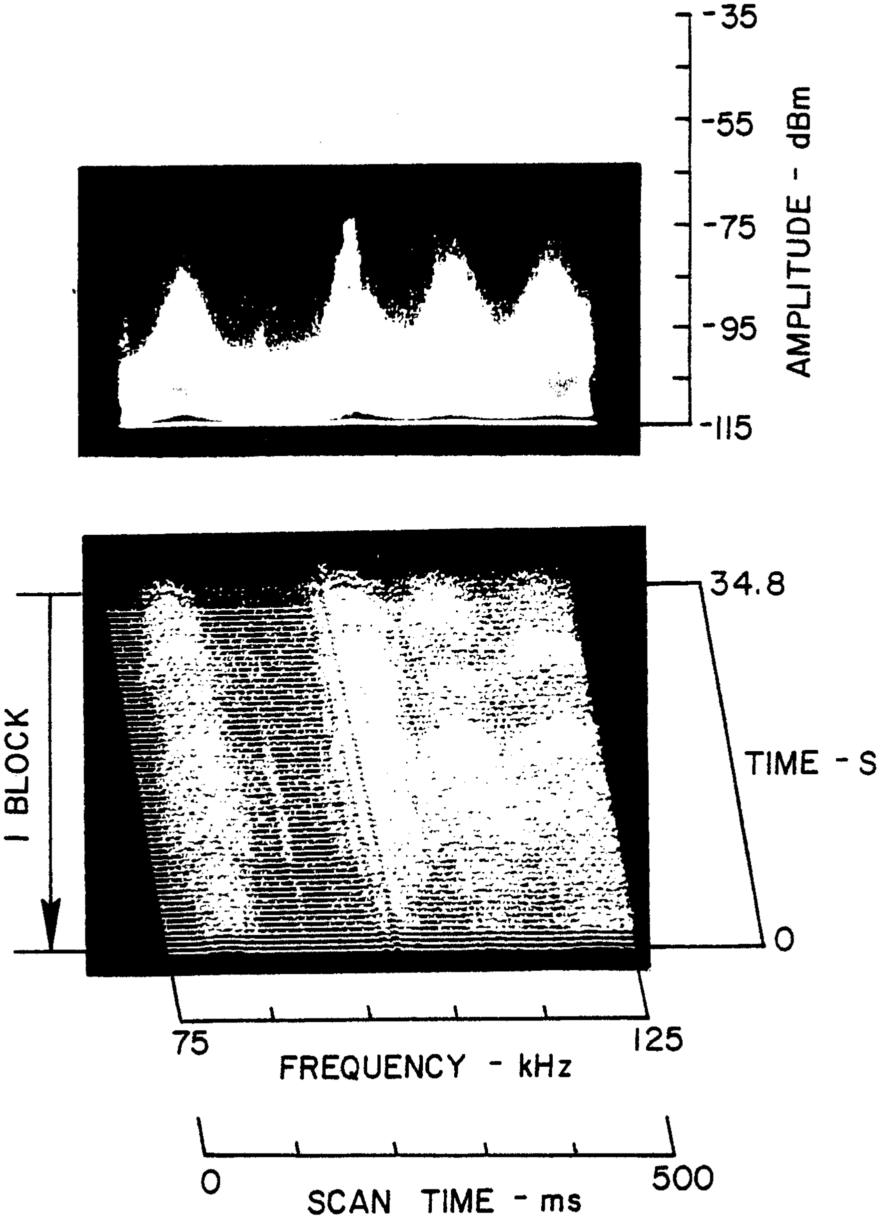


Figure 7 3-Axis View, 1/22/79, 1220, Approaching 106-010

1/23/79, 0827, leaving 109-014
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

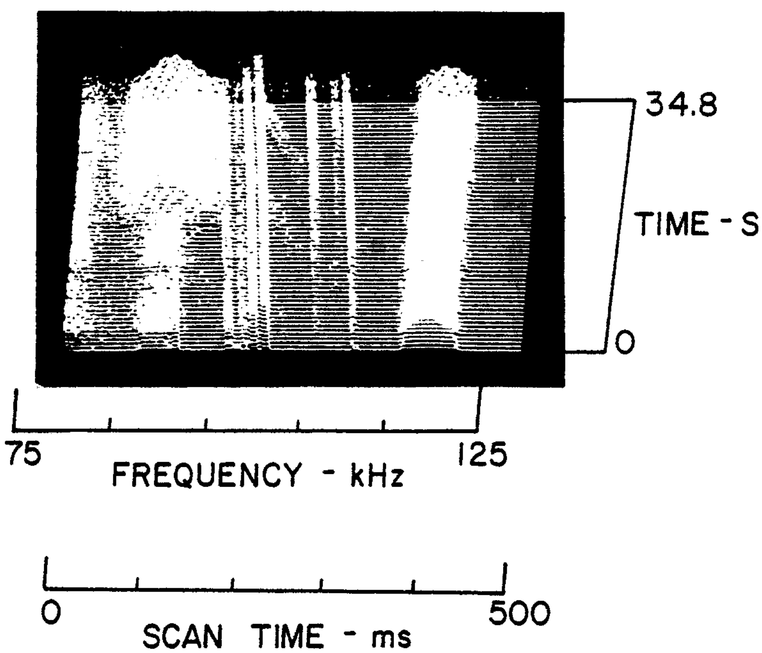


Figure 8 3-Axis View, 1/23/79, 0827, Leaving 109-014

1/23/79, 0916, from Sepulveda onto Wilmington
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

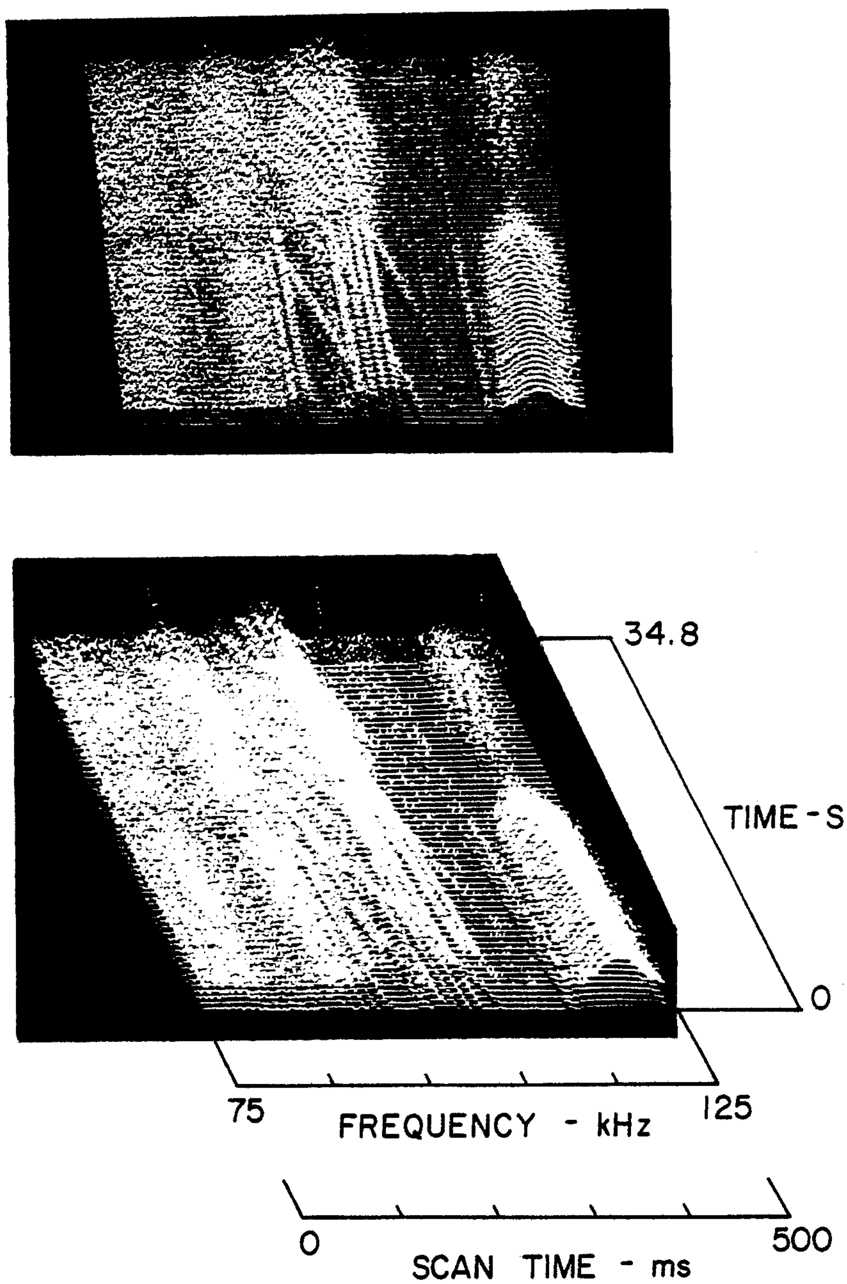


Figure 9 3-Axis View, 1/23/79, 0916, From Sepulveda onto Wilmington

1/23/79, 0918, two locations on Wilmington 1/2 mile apart
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A −20 dBm/0/+15 dB/NF

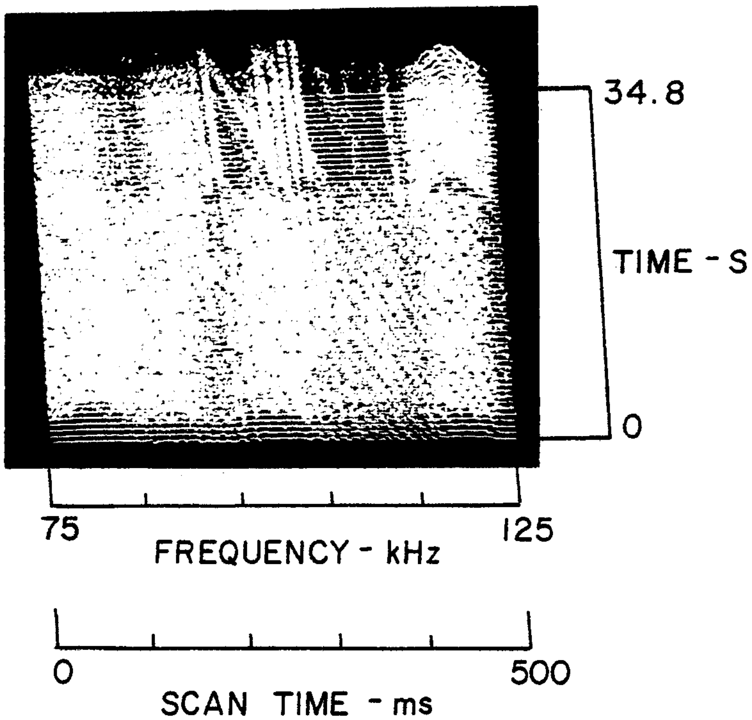


Figure 10 3-Axis View, 1/23/79, 0918, Two Locations on Wilmington

3.3.3 Spatial Variations in Impulsive Noise

Results of the Phase I measurements showed that large changes occurred in impulsive noise levels as the measurement van approached and departed from the vicinity of certain electric utility distribution lines. The source of the impulsive noise was believed to be high power control units containing solid state switching devices employed by utility customers. Similar cases of spatial variation were also observed during the Phase II measurements.

A very large and sudden change in impulsive noise levels can be seen in Figure 11 where the measurement van turned off Del Amo onto Tillman. The very strong impulsive noise along Del Amo completely disappeared in less than 100' of travel on Tillman. The peak amplitude of the noise changed more than 70 dB in strength from Del Amo to Tillman. Another view of the impulsive noise on Del Amo is shown in Figure 12 at the corner of Del Amo and Anza. The noise along Del Amo at Anza was about 25 dB below the very high level at Del Amo and Tillman.

Data taken at site 109-018 (see Appendix A) were free of impulsive noise. However, 100' further along Watson Center Road strong impulsive noise conditions were observed which were associated with a 12 KV electric utility distribution line that terminated about 100' from the fixed measurement site. Figure 13 shows the impulsive noise encountered as the measurement van turned into a parking lot at the end of the distribution line, pulled away from the line during a wide turn in the parking lot, and then passed under the same line at a second parking lot entrance about 200' from the 109-018 site. The strong dependence of noise level on spatial movements is clearly shown. Additional impulsive noise measurements at a fixed location along Watson Center Road 100' from the actual 109-018 site are shown in Figures 14 and 15. The impulses are evenly spaced at about 2.6 ms intervals. Figure 14 shows variations in amplitude of the noise impulses over a 50 kHz wide band of frequencies and Figure 15 shows variations in amplitude over a 100 kHz wide band of frequencies.

1/23/79, 0944, from Del Amo onto Tillman
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

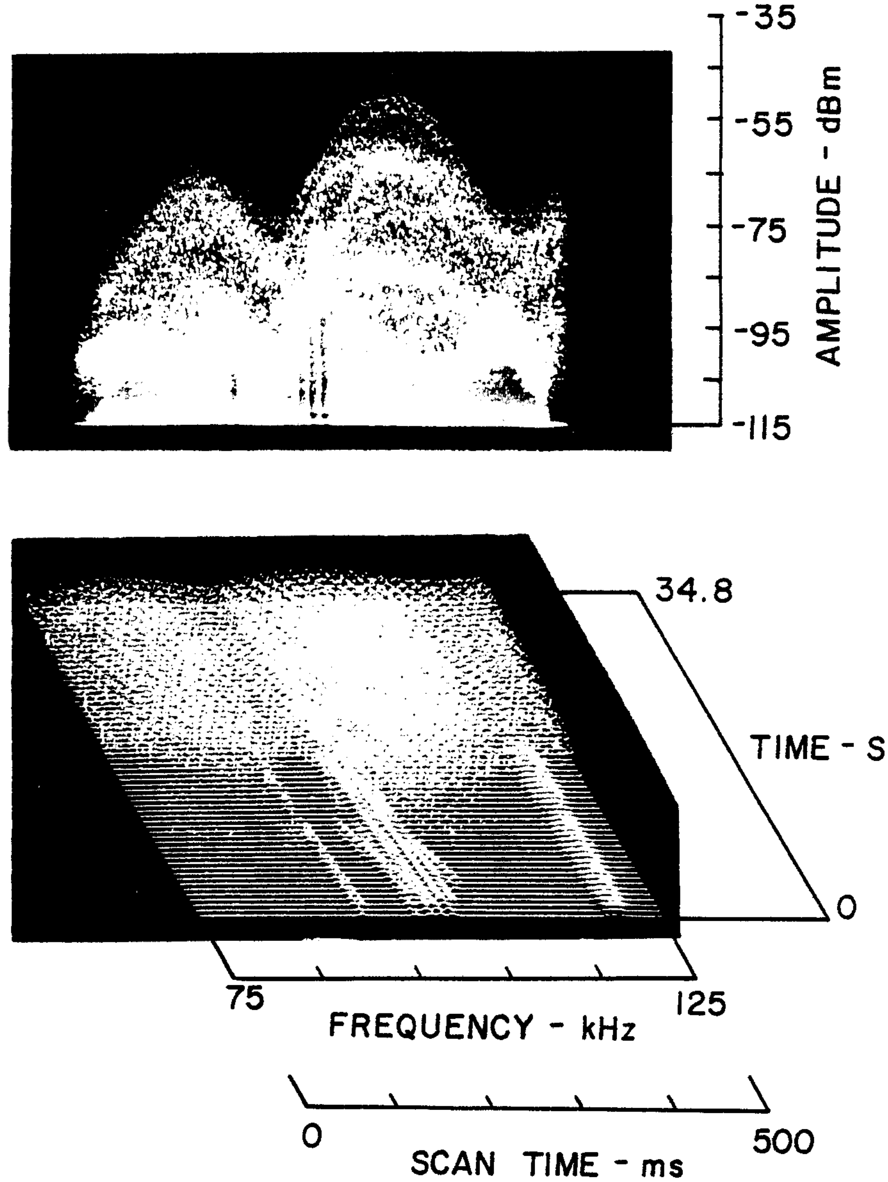


Figure 11 3-Axis View, 1/23/79, 0944, From Del Amo onto Tillman

1/22/79, 1125, Del Amo and Anza
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -30 dBm/0/+15 dB/NF

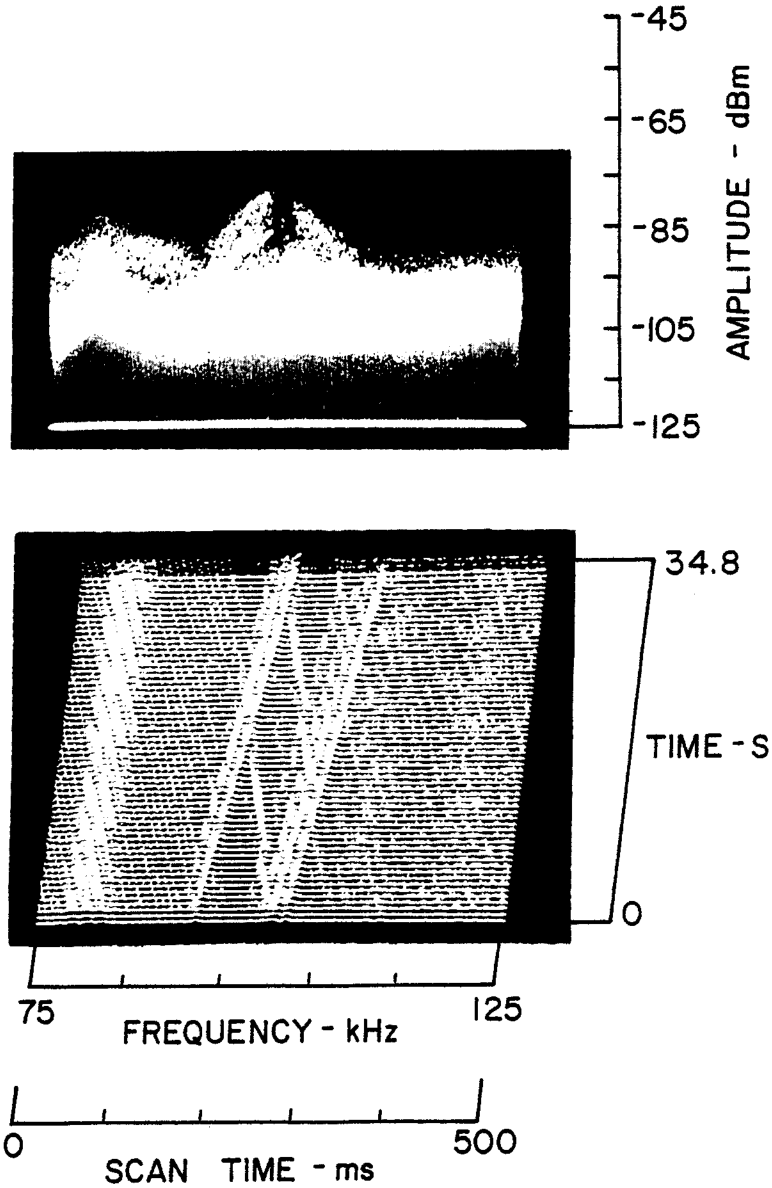


Figure 12 3-Axis View, 1/22/79, 1125, Del Amo and Anza

1/23/79, 0942, leaving 109-018 and u-turn under distribution line
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, A -20 dBm/0/+15 dB/NF

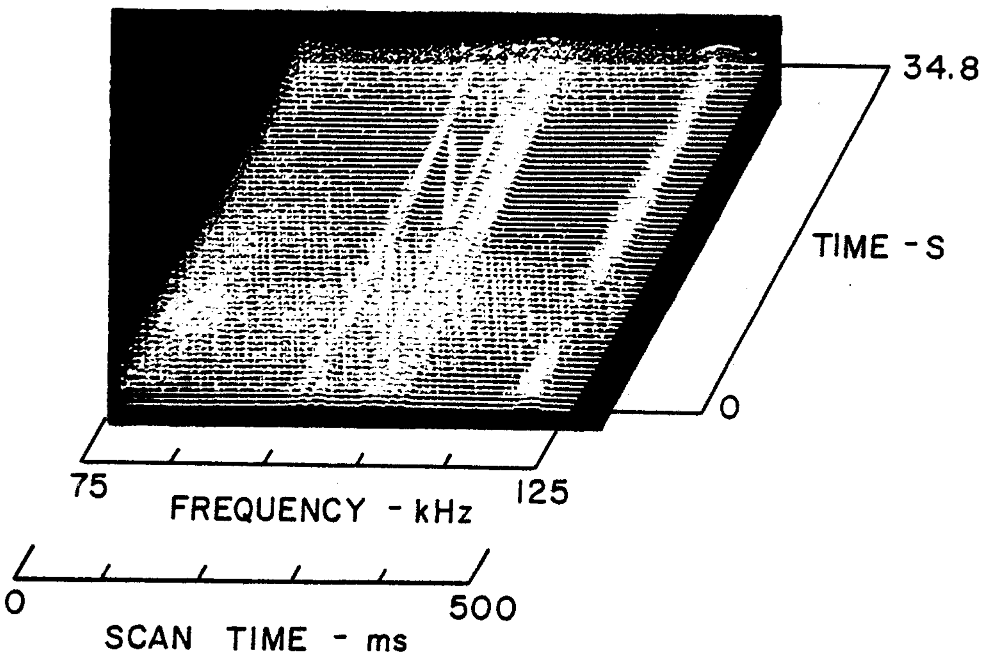
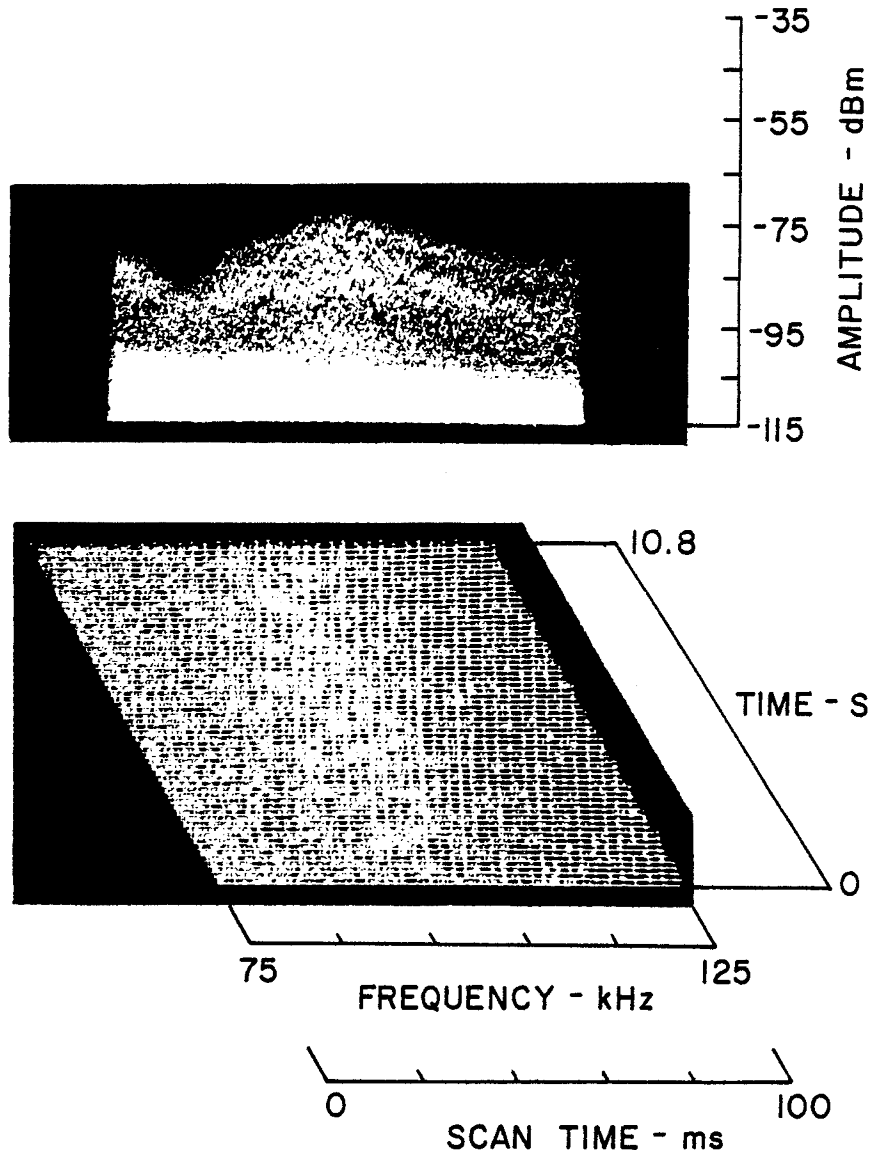


Figure 13 3-Axis View, 1/23/79, 0942, Leaving 109-018



1/26/79, 0920, 109-018 Site 2
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 100 ms, A -20 dBm/0/+15 dB/NF

Figure 14 3-Axis View, 1/26/79, 0920, 109-018 Site 2

1/26/79, 0923, 109-018 Site 2
HP 140, Whip, F 100 kHz, W 100 kHz, IF 3 kHz, ST 100 ms, A -20 dBm/0/+15 dB/NF

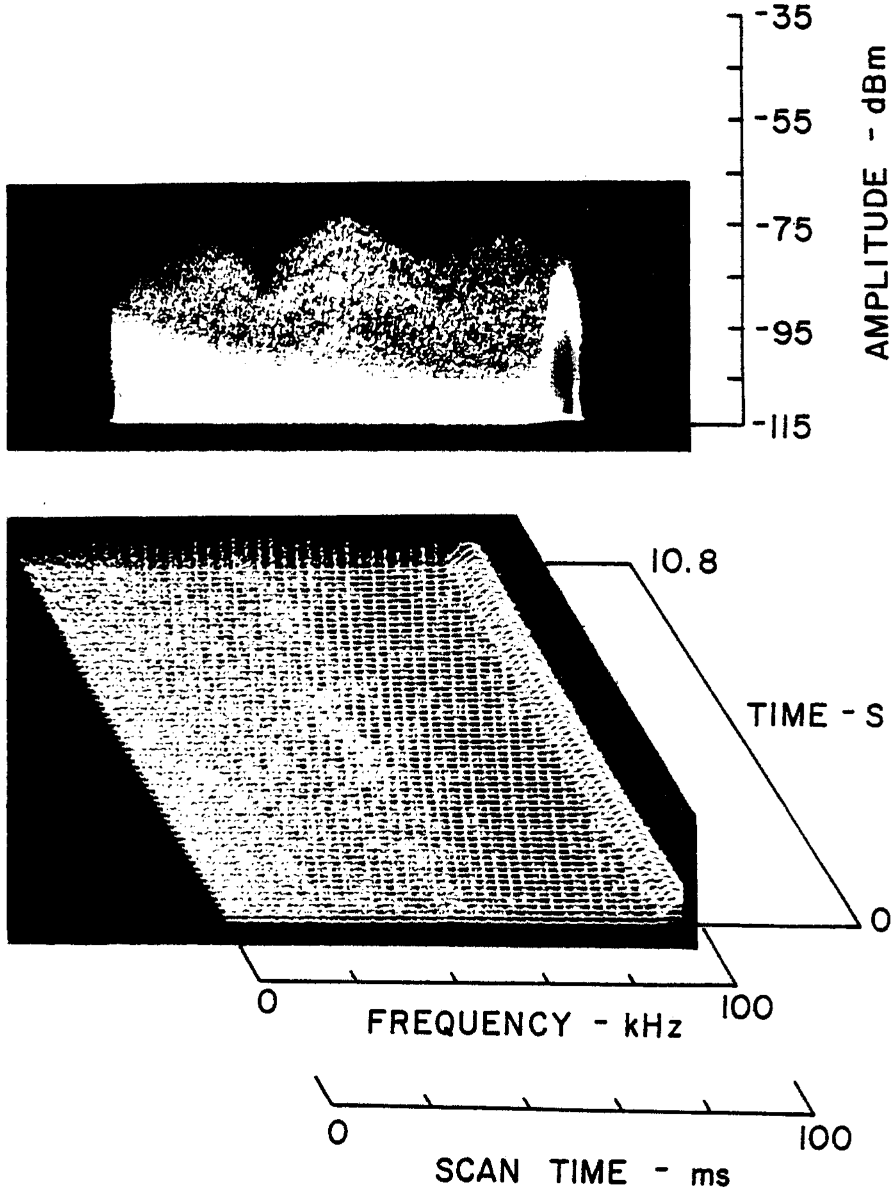


Figure 15 3-Axis View, 1/26/79, 0923, 109-018 Site 2